

# **What Every Systems Engineer Ought to Know About Lean Six Sigma**

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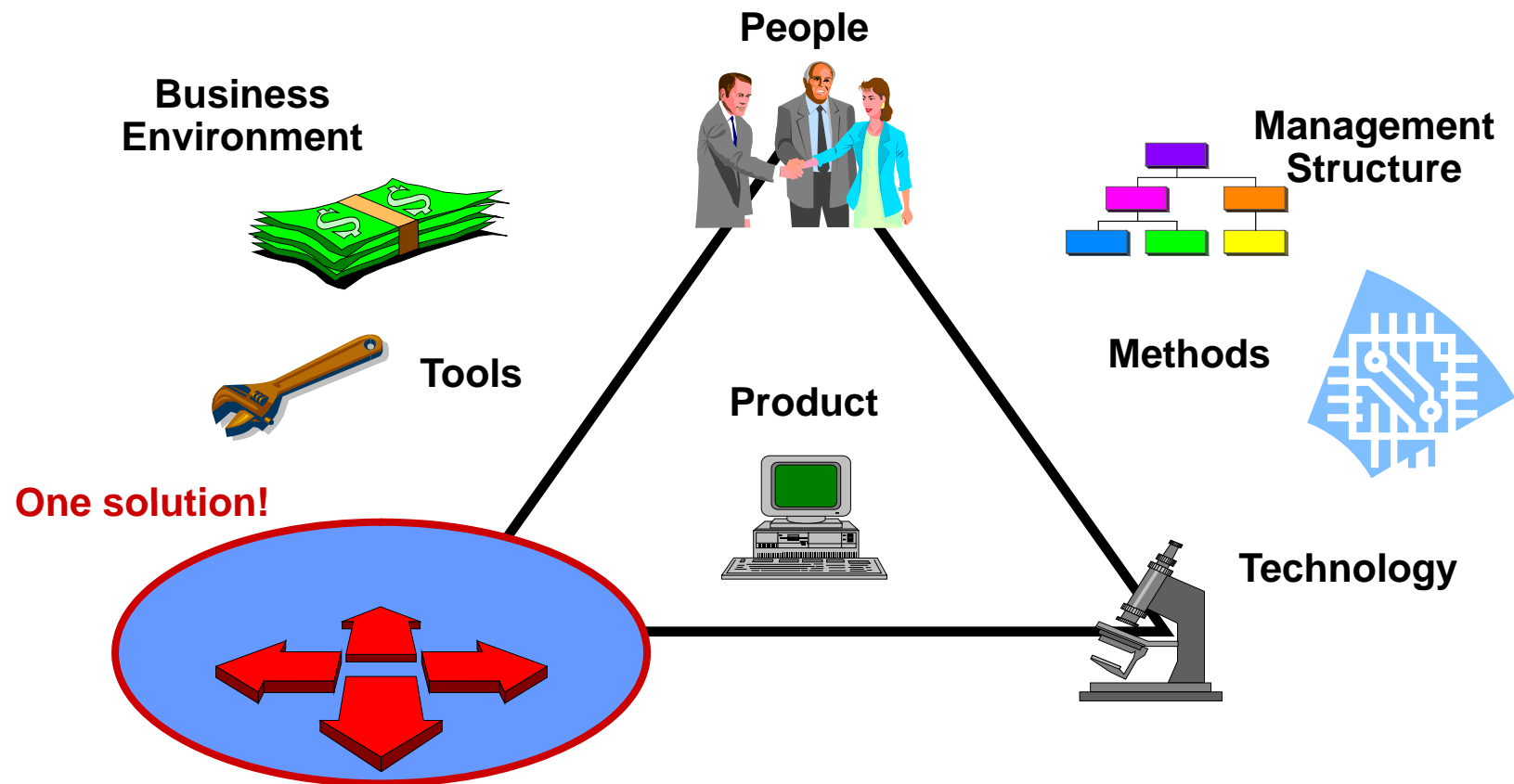
- **Six Sigma has proven to be a powerful enabler for process improvement**
  - CMMI adoption
  - Process improvement for measurable ROI
  - Statistical analysis
- **This presentation will focus on practical tools and techniques for use by systems engineers**

## Agenda

- **What is Six Sigma?**
- **How does it apply to systems engineering?**
- **Strategies and lessons learned**

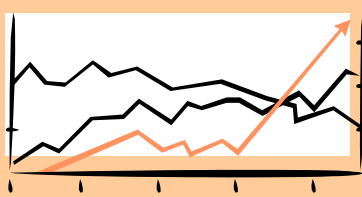
# Many Approaches to Solving the Problems

- Which weaknesses are causing my problems?
- Which strengths may mitigate my problems?
- Which improvement investments offer the best return?



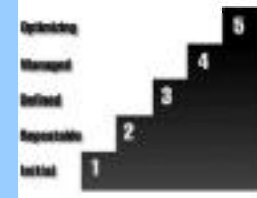
# Approaches to Process Improvement

## *Data-Driven (e.g., Six Sigma, Lean)*



- **Clarify what your customer wants (Voice of Customer)**
  - Critical to Quality (CTQs)
- **Determine what your processes can do (Voice of Process)**
  - Statistical Process Control
- **Identify and prioritize improvement opportunities**
  - Causal analysis of data
- **Determine where your customers/competitors are going (Voice of Business)**
  - Design for Six Sigma

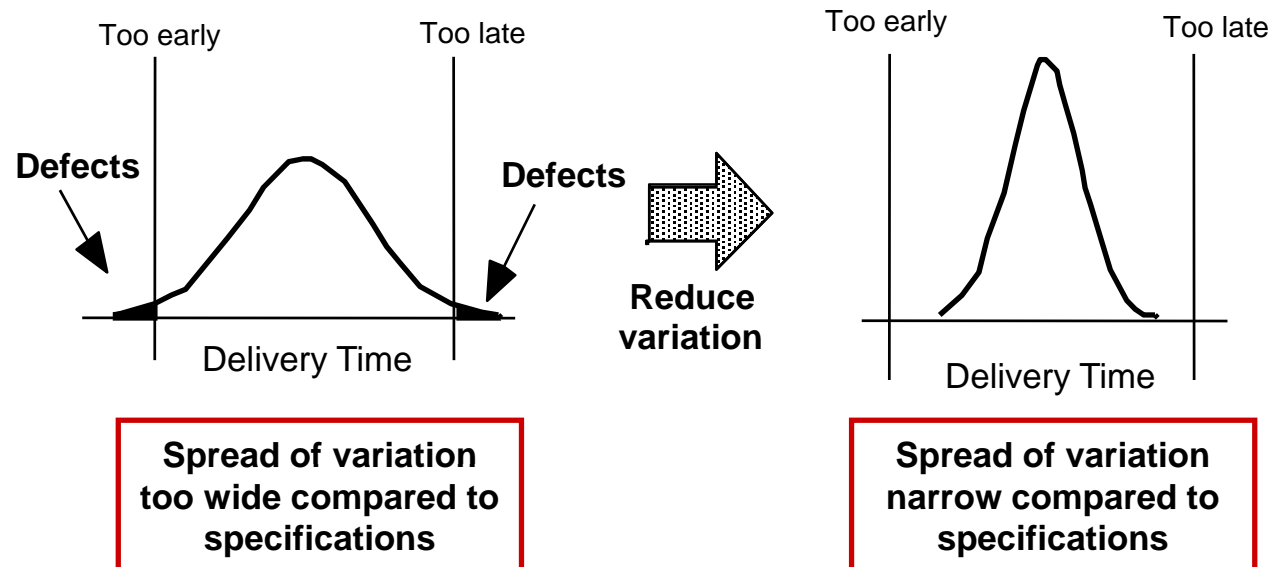
## *Model-Driven (e.g., CMM, CMMI)*



- **Determine the industry best practice**
  - Benchmarking, models
- **Compare your current practices to the model**
  - Appraisal, education
- **Identify and prioritize improvement opportunities**
  - Implementation
  - Institutionalization
- **Look for ways to optimize the processes**

# What is Six Sigma?

- **Six Sigma is a management philosophy based on meeting business objectives by reducing variation**
  - A disciplined, data-driven methodology for decision making and process improvement
- **To increase process performance, you have to decrease variation**



- Greater predictability in the process
- Less waste and rework, which lowers costs
- Products and services that perform better and last longer
- Happier customers

# A Typical Six Sigma Project in Systems Engineering

- The organization notes that systems integration has been problematic on past projects (budget/schedule overruns)
- A Six Sigma team is formed to scope the problem, collect data from past projects, and determine the root cause(s)
- The team's analysis of the historical data indicates that poorly understood interface requirements account for 90% of the overruns
- Procedures and criteria for a peer review of the interface requirements are written, using best practices from past projects
- A pilot project uses the new peer review procedures and criteria, and collects data to verify that they solve the problem
- The organization's standard SE process and training is modified to incorporate the procedures and criteria, to prevent similar problems on future projects

- **System engineering processes are fuzzy**
  - Systems engineering "parts" are produced using processes lacking predictable mechanizations assumed for manufacturing of physical parts
  - Simple variation in human cognitive processes can prevent rigorous application of the Six Sigma methodology
  - Process variation can never be eliminated or may not even reduced below a moderate level
- **Results often cannot be measured in clear \$ savings returned to organization**
  - Value is seen in reduced risk, increased customer satisfaction, more competitive bids, ...



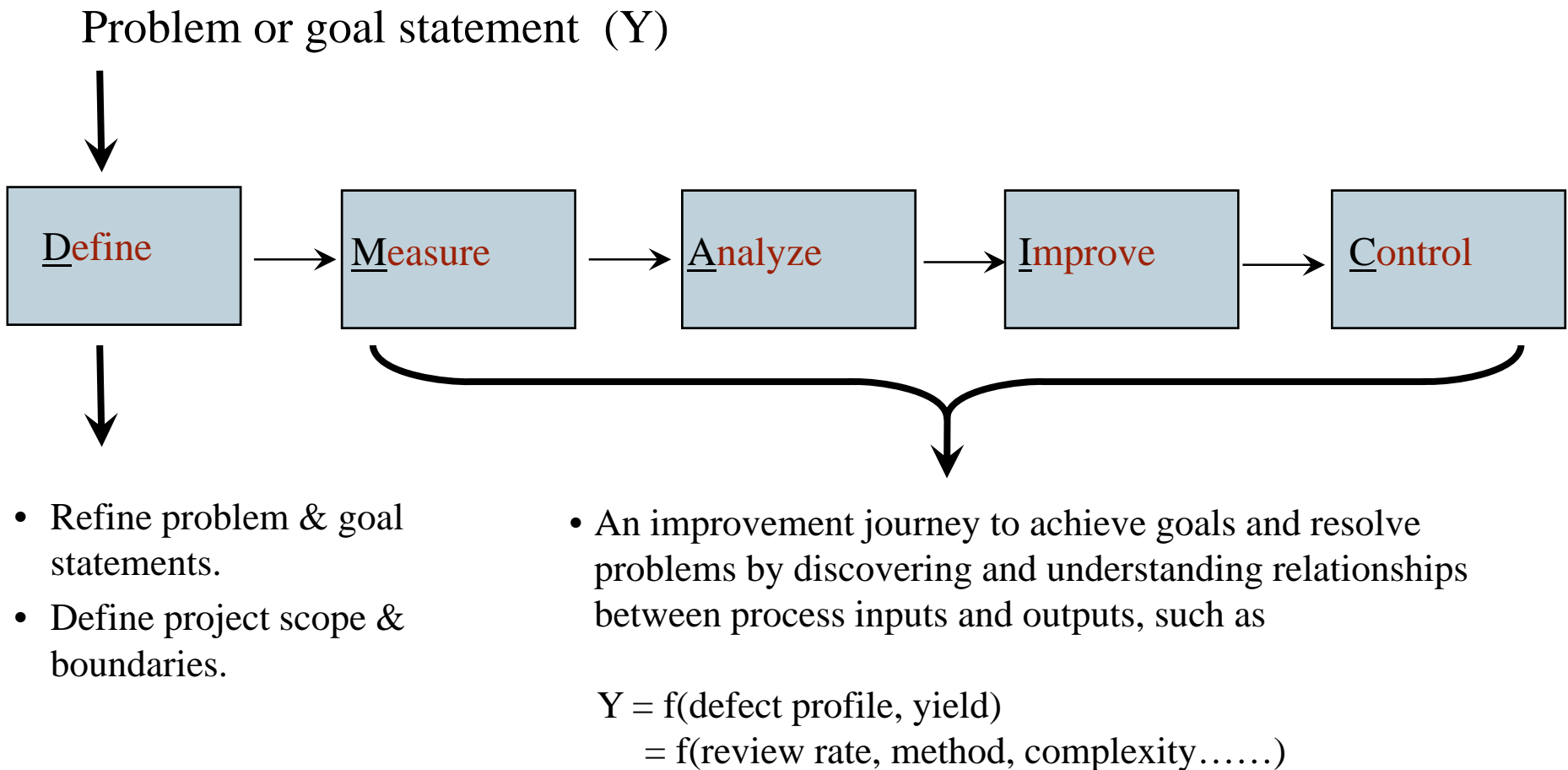
- **Capturing the first, “low hanging fruit” makes Six Sigma implementation look easy...**
  - Clearer problems, simpler solutions, bigger payoffs
  - Little need for coordination
- **...but later projects are tougher**
  - Keeping projects appraised of similar efforts, past and current
  - Focusing on “the pain”, not the assumed solution
- **Engineering process measurements are often difficult to analyze**
  - Dirty (or no) data, human recording problems
  - May necessitate Define-Measure-Analyze-Measure-Analyze-etc.
- **Must demonstrate the value of quantitative data to managers**
  - Management style - reactive vs. proactive vs. quantitative
  - Less value in a chaotic environment
  - Must engage customers

- **Difficulty in collecting subjective, reliable data**
  - Humans are prone to errors and can bias data
  - E.g., the time spent in privately reviewing a document
- **Dynamic nature of an on-going project**
  - Changes in schedule, budget, personnel, etc. corrupt data
- **Analysis requires that complex SE processes be broken down into small, repeatable tasks**
  - E.g., peer review
- **Repeatable process data requires the project/organization to define (and follow) a detailed process**

# Strategies & Lessons Learned

- **Six Sigma provides a comprehensive set of tools for:**
  - Soliciting and understanding customer needs (requirements, delighters, perceptions of quality)
  - Defining and improving processes (inputs/outputs, customer/suppliers, essential/nonessential activities, capability, stability/predictability)
  - Understanding data (trends, relationships, variation)
- **These tools can be used even if your organization is not implementing Six Sigma**

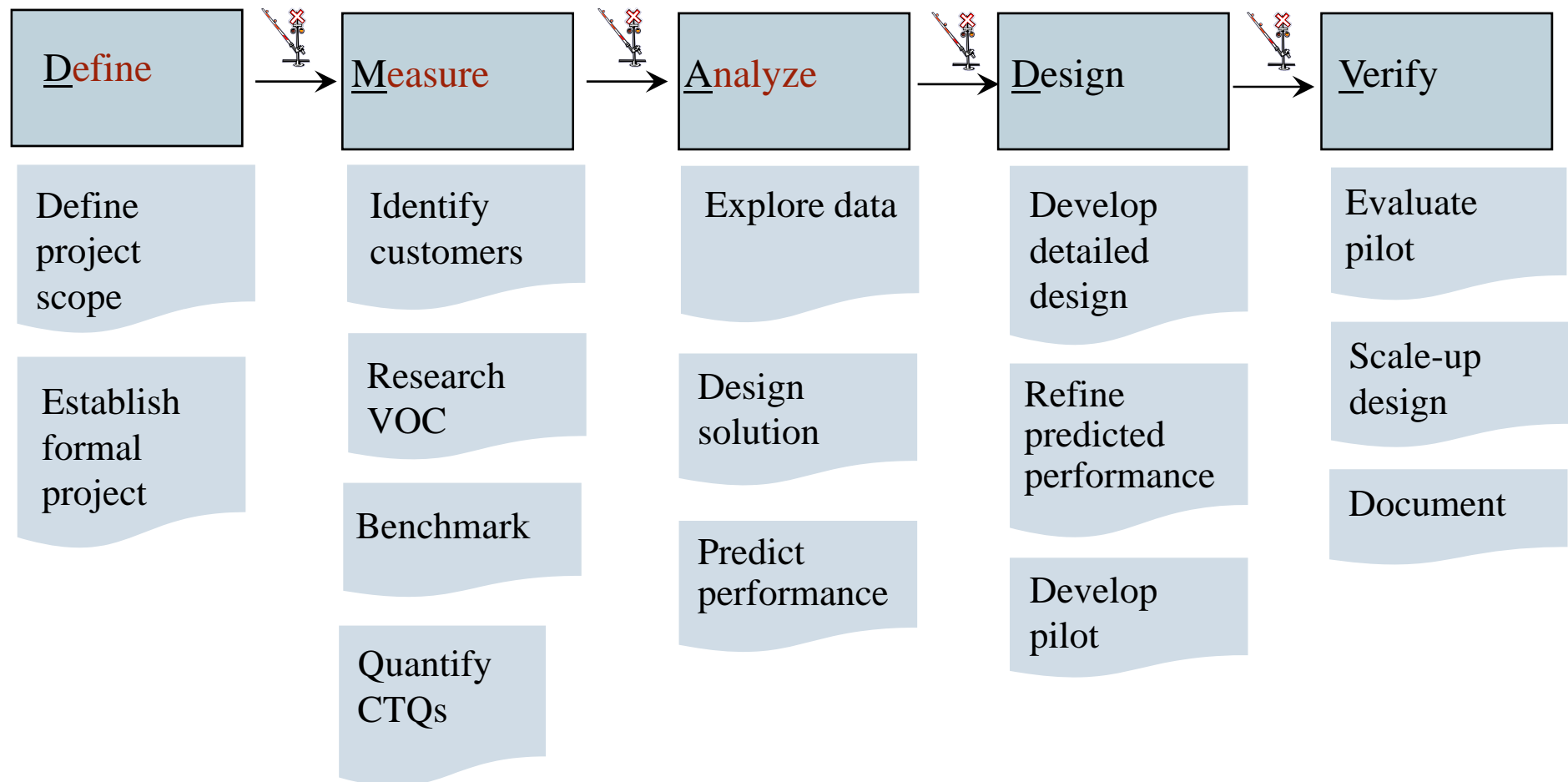
# A General Purpose Problem-Solving Methodology: DMAIC



# Toolkit

Define	Measure	Analyze	Improve	Control
<p>Benchmark</p> <p>Contract/Charter</p> <p>Kano Model</p> <p>Voice of the Customer</p> <p>Voice of the Business</p> <p>Quality Function Deployment</p>	<p>GQIM and Indicator Templates</p> <p>Data Collection Methods</p> <p>Measurement System Evaluation</p>	<p>Cause &amp; Effect Diagrams/ Matrix</p> <p>Failure Modes &amp; Effects Analysis</p> <p>Statistical Inference</p> <p>Reliability Analysis</p> <p>Root Cause Analysis, including 5 Whys</p> <p>Hypothesis Test</p>	<p>Design of Experiments</p> <p>Modeling</p> <p>ANOVA</p> <p>Tolerancing</p> <p>Robust Design</p> <p>Systems Thinking</p> <p>Decision &amp; Risk Analysis</p> <p>PSM Perform Analysis Model</p>	<p>Statistical Controls:</p> <ul style="list-style-type: none"> <li>• Control Charts</li> <li>• Time Series methods</li> </ul> <p>Non-Statistical Controls:</p> <ul style="list-style-type: none"> <li>• Procedural adherence</li> <li>• Performance Mgmt</li> <li>• Preventive measures</li> </ul>
<p>7 Basic Tools (Histogram, Scatter Plot, Run Chart, Flow Chart, Brainstorming, Pareto Chart), Control charts (for diagnostic purposes), Baseline, Process Flow Map, Project Management, "Management by Fact", Sampling Techniques, Survey Methods, Defect Metrics</p>				

# Design for Six Sigma (e.g., DMADV)



# The Voices of Six Sigma

- **Six Sigma includes powerful techniques for understanding the problem you are trying to solve**
  - Voice of Customer
  - Voice of Process
  - Voice of Business
- **These techniques are useful in non-Six Sigma settings for understanding:**
  - Customer requirements and needs
  - Process performance and capability
  - Business priorities and trends





- **A process used to capture the requirements/feedback from the customer (internal or external)**
  - Proactive and continuous
  - Stated and unstated needs
  - “Critical to Quality (CTQ)”- What does the customer think are the critical attributes of quality?
- **Approaches:**
  - Customer specifications
  - Interviews, surveys, focus groups
  - Prototypes
  - Bug reports, complaint logs, etc.
  - House of Quality

- **VOC approaches provide powerful methods for eliciting, analyzing, and validating requirements**
- **Can overcome common problems by:**
  - Identifying ALL the customers
  - Identifying ALL their requirements
  - Probing beyond the stated requirements for needs
  - Understanding the requirements from the customers' perspective
  - Recognizing and resolving conflicts between requirements or between requirement providers

# Identifying Needed Data

*What are the process outputs and performance measures?*

*What are the inputs? What are the relationships among outputs and inputs?*

- We need to find out what contributes to performance:

- What are the process outputs (y's) that drive performance?
- What are key process inputs (x's) that drive outputs and overall performance?

- Techniques to address these questions

- segmentation / stratification
- input and output analysis
- y to x trees
- cause & effect diagrams

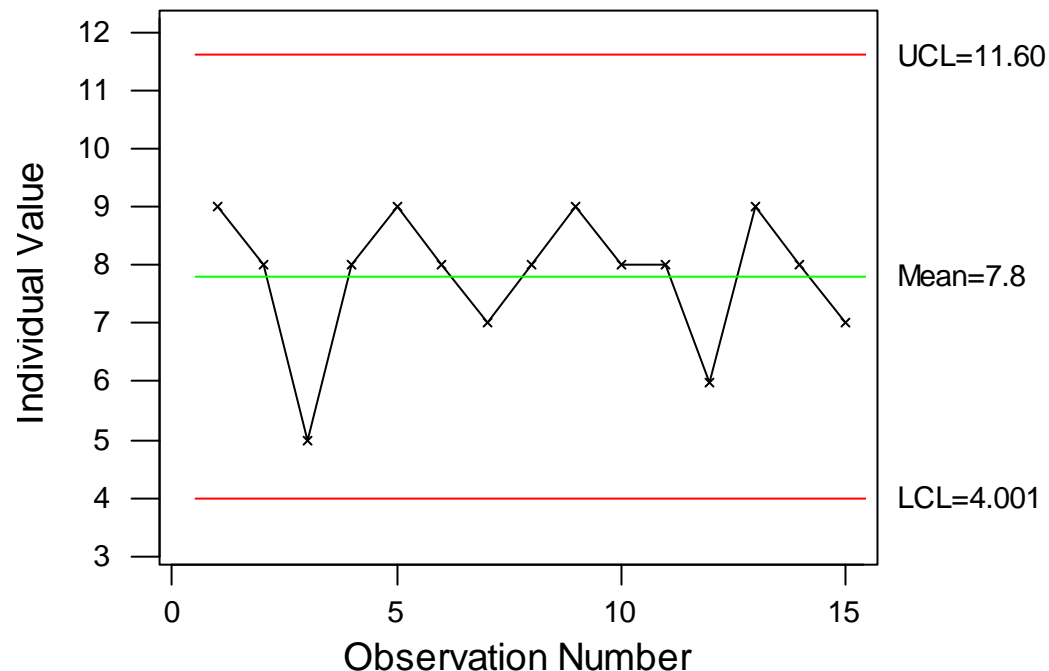
*Using these techniques yields a list of relevant, hypothesized, process factors to measure and evaluate.*

# Controlled and Uncontrolled Factors

- **Controlled factors are within the project team's scope of authority and are accessed during the course of the project.**
- **Studying their influence may inform:**
  - cause-and-effect work during Analyze
  - solution work during Improve
  - monitor and control work during Control
- **Uncontrolled factors are factors we do not or cannot control**
- **We need to acknowledge their presence and, if necessary, characterize their influence on Y**
- **A robust process is insensitive to the influence of uncontrollable factors**

# Exercise – What is Quantitative Management?

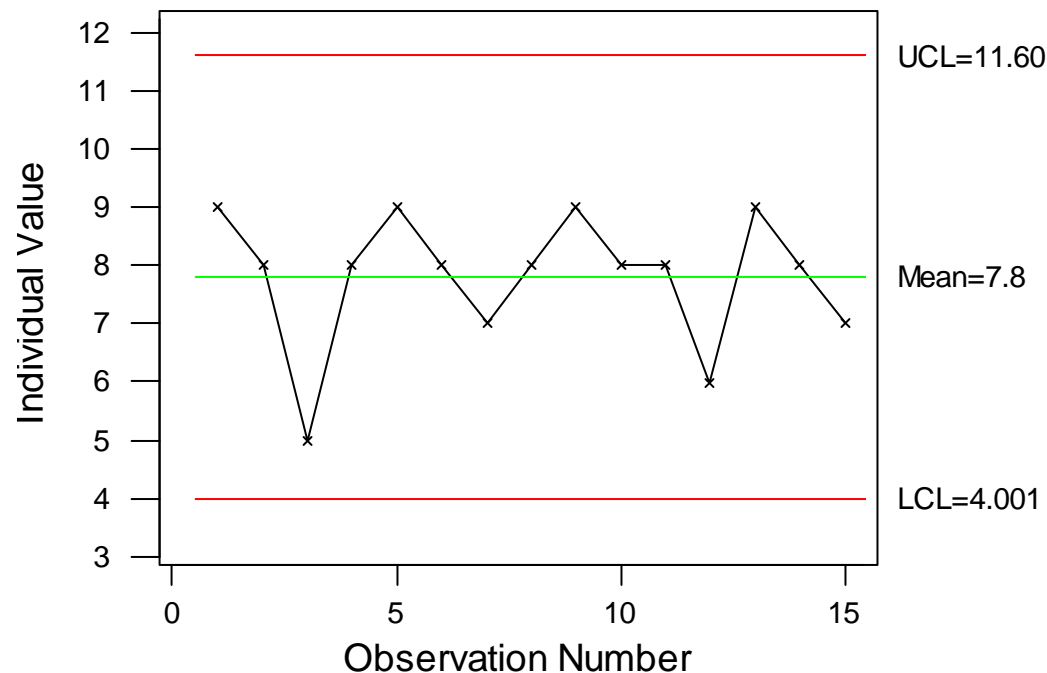
- **Suppose your project conducted several peer reviews of similar code, and analyzed the results**
  - Mean = 7.8 defects/KSLOC
  - $+3\sigma = 11.60$  defects/KSLOC
  - $-3\sigma = 4.001$  defects/KSLOC



- **What would you expect the next peer review to produce in terms of defects/KSLOC?**
- **What would you think if a review resulted in 10 defects/KSLOC?**
- **3 defects/KSLOC?**

# Exercise – What is Required for Quantitative Management?

- What is needed to develop the statistical characterization of a process?



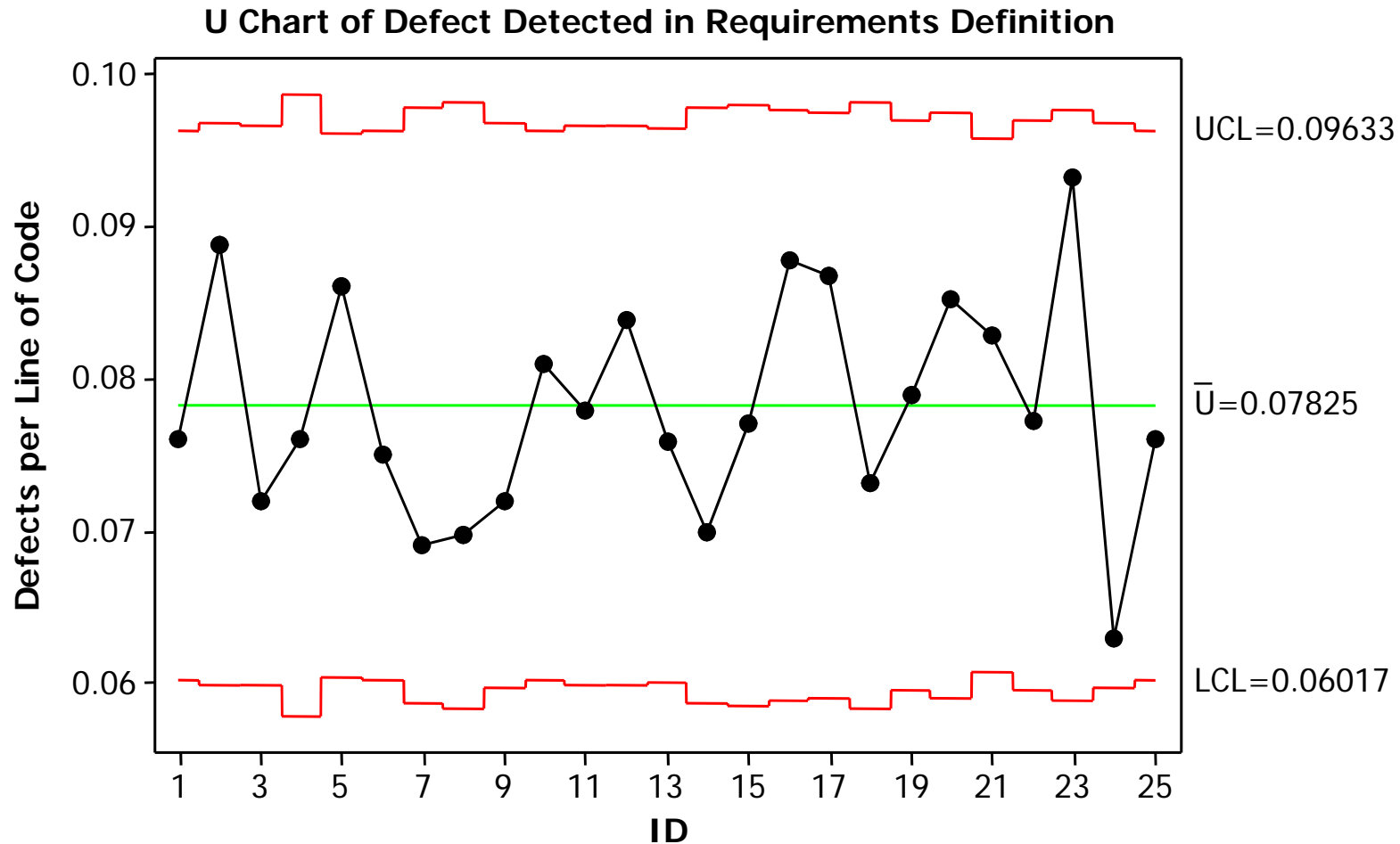
- The process has to be **stable (predictable)**
  - Process must be consistently performed
  - Complex processes may need to be stratified (separated into simpler processes)
- There has to be enough **data points to statistically characterize the process**
  - Processes must occur frequently within a similar context (project or organization)

# What Is a Control Chart?



- A time-ordered plot of process data points with a centerline based on the average and control limits that bound the expected range of variation
- Control charts are one of the most useful quantitative tools for understanding variation

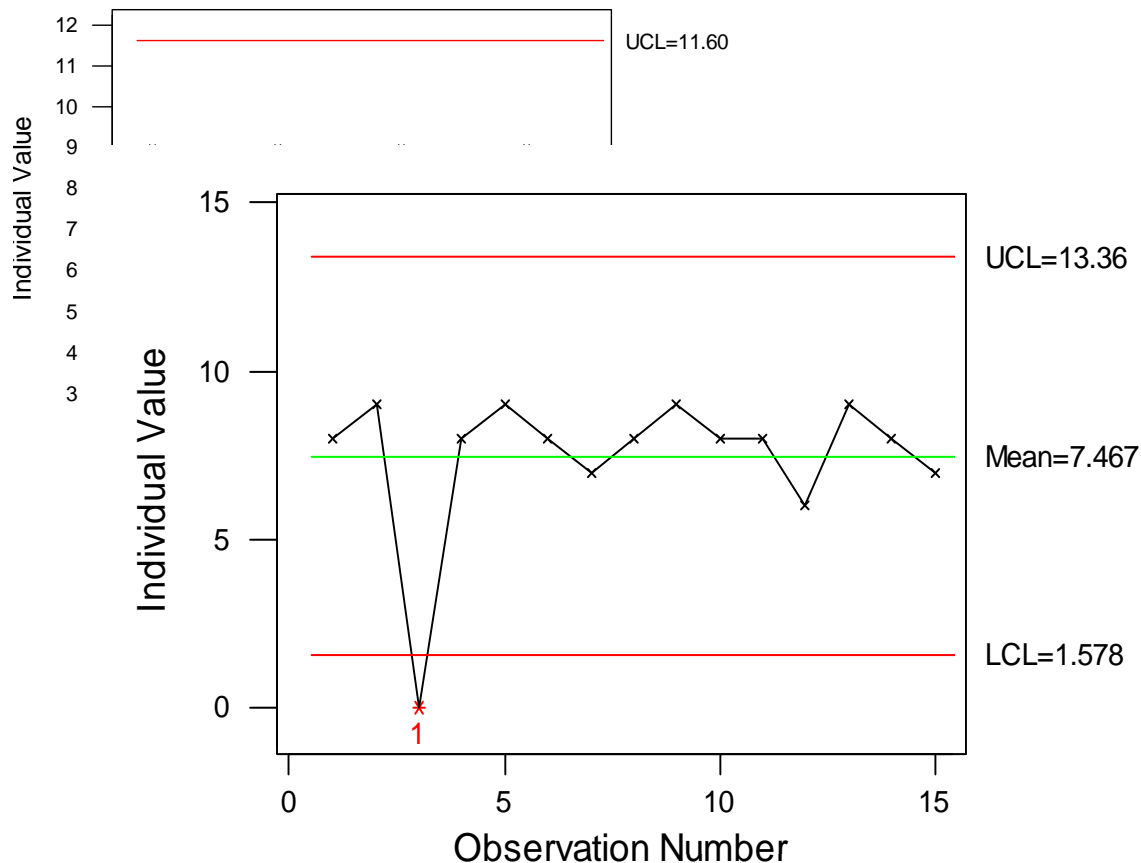
# There are Many Types of Control Charts



Tests performed with unequal sample sizes



# What is *Special Cause* and *Common Cause* Variation?



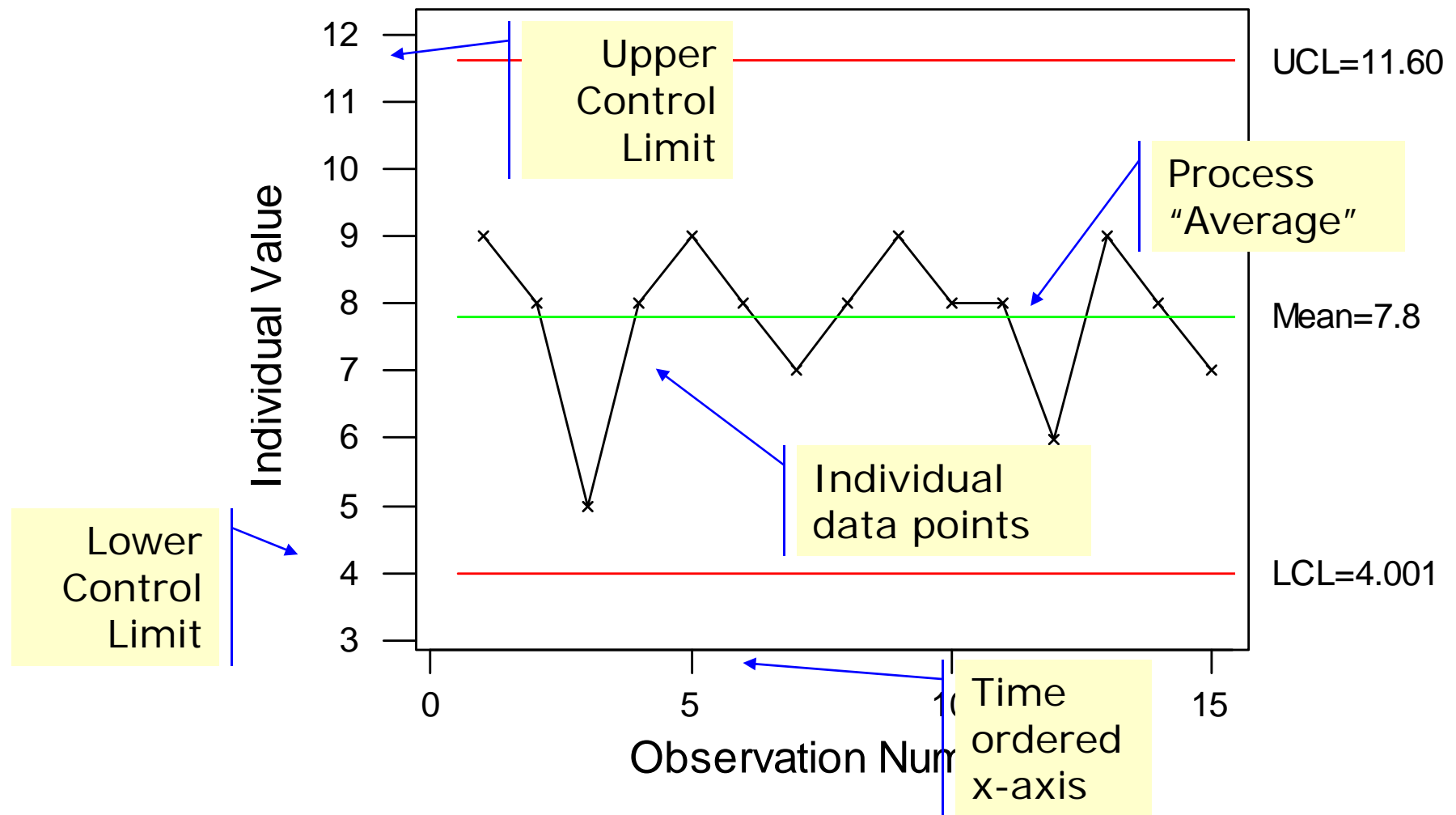
- **Common Cause Variation**

- *Routine* variation that comes from within the process
- Caused by the natural variation in the process
- Predictable (stable) within a range

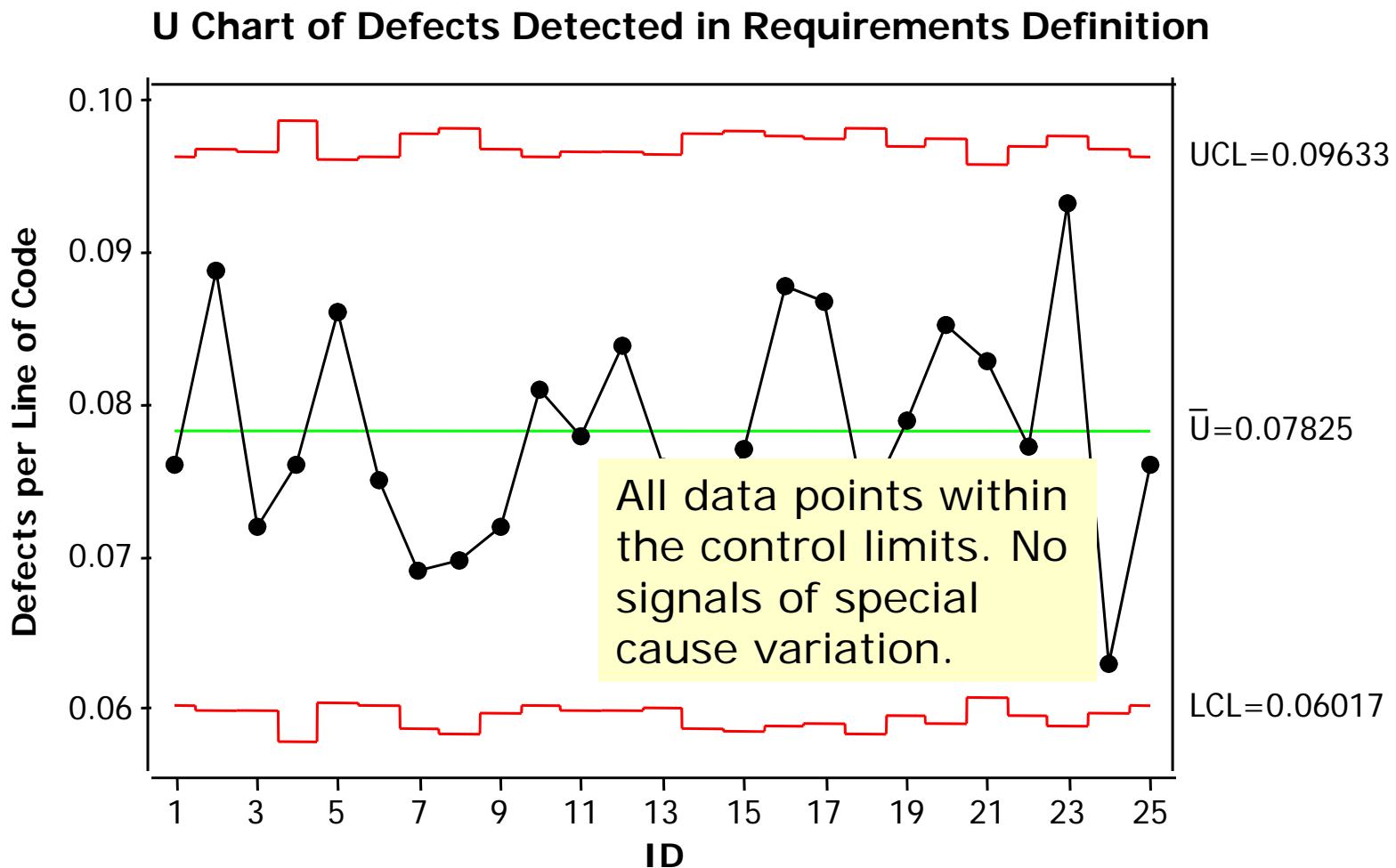
- **Special Cause Variation**

- *Assignable* variation that comes from outside the process
- Caused by a unexpected variation in the process
- Unpredictable

# What Are the Key Features of a Control Chart?

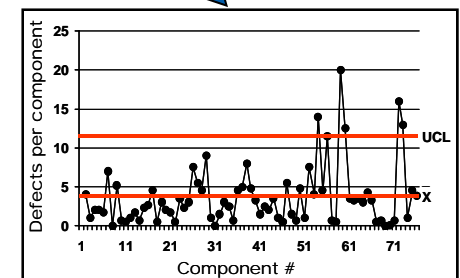
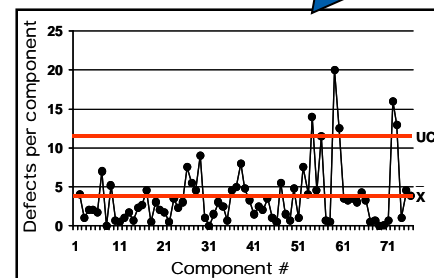
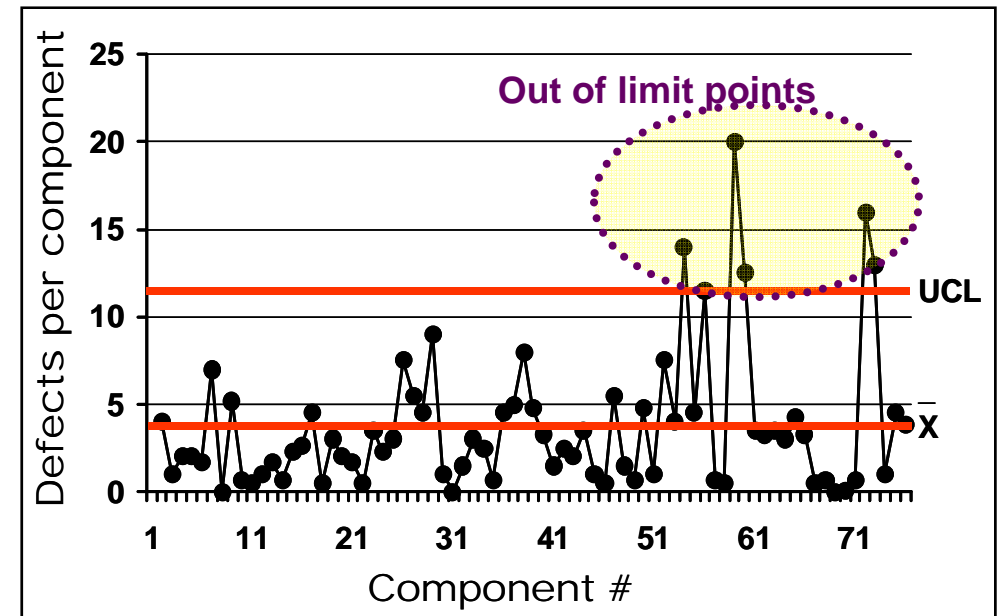


# What Is a *Stable* (Predictable) Process?



# What if the Process Isn't Stable?

- You may be able to explain out of limit points by observing that they are due to an variation in the process
  - E.g., peer review held on Friday afternoon
  - You can eliminate the points from the data, if they are not part of the process you are trying to predict
- You may be able to stratify the data by an attribute of the process or attribute of the corresponding work product
  - E.g., different styles of peer reviews, peer reviews of different types of work products



# References – Six Sigma

- Rick Hefner and Jeannine Siviya, "Six Sigma Tools for Early Adopter, Software Engineering Process Group conference, 2005
- [www.isixsigma.com](http://www.isixsigma.com)
- David Card, "Sorting Out Six Sigma and the CMM", IEEE Software, May 2000
- Jeannine Siviya, et al, "Software Technology Review (Six Sigma Section)", <http://www.sei.cmu.edu/str/>
- Larry Smith, "Six Sigma and the Evolution of Quality in Product Development," Six Sigma Forum Magazine, Vol. 1, Issue 1, Nov 2001, [www.asq.org/pub/sixsigma/evolution.html#fig2back](http://www.asq.org/pub/sixsigma/evolution.html#fig2back)
- Rath & Strong, "Six Sigma Pocket Guide"
- Donald J. Wheeler, Understanding Variation: The Key to Managing Chaos
- Breyfogle III, Forrest W., Implementing Six Sigma: Smarter Solutions Using Statistical Methods

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